F1-305

ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY
Chief Financial Officer
1 Cyclotron Road, MS90-1070
Berkeley, CA 94720
510.486.4126 (voice) * 510.486.4386 (fax)

CFO/Sponsored Projects Office

July 28, 1997

CALFED BAY-DELTA PROGRAM
1416 Ninth Street, Suite 1155
Sacramento, CA 95814

Attn: Ms. Kate Hansel

JUL 28 1997

Phone: (916) 657-2666
Fax: (916) 654-9780

REFERENCE REPLY: LBNL Proposal #BG97-361 (00)

Dear Ms. Hansel:

Enclosed for your consideration is an original copy of the subject proposal submitted on behalf of the E. O. Lawrence Berkeley National Laboratory (LBNL):

Title:	Biological Metals Removal for the Treatment of Acid Mine Drainage in the Sacramento Valley
Principal Investigator:	William T. Stringfellow
Total Amount Requested:	$1,827,751
Period Requested:	3 years from date of execution
Type of Request:	New

Ernest Orlando Lawrence Berkeley National Laboratory is operated by The Regents of the University of California for the Department of Energy (DOE) under prime contract DE-AC03-76SF00098 and all work is conducted under the terms of that contract and subject to the approval of DOE. This proposal will be submitted to DOE for approval.

Should you decide to make an award, an interagency agreement for performance at LBNL should be sent to my attention consistent with the enclosed Administrative Instructions to Other Federal Agencies for Submission of Interagency Agreements for Reimbursable Work. I will coordinate final acceptance with DOE and return a fully-executed copy to your office.

Such agreement must include the following language:

> "This agreement is entered into pursuant to the Authority of the Economy Act of 1932, as amended (31 U.S.C. 1535), and adheres to Federal Acquisition Regulation (FAR) 6.002 and other applicable Federal Laws and Regulations. To the best of our knowledge, the work requested will not place the DOE and its contractor in direct competition with the private sector."

This document is submitted in confidence prior to the completion of review for possible patentable inventions and subsequent filing of patent applications. Accordingly, this document is exempt from disclosure under the Freedom of Information Act under 5 USC 553(b)(3) & (b)(4) and implementing regulations, such as Executive Order 12,600 of June 23, 1987. Please do not make this document available to the public without permission.

If you have any questions regarding this submission, please feel free to call me on (510) 486-7324 or Facsimile No. (510) 486-4386. For technical matters, please call William T. Stringfellow at (510) 486-7903.

Sincerely,

Cole B. Cannon

Cole Cannon
Contracts Officer
CFO/Sponsored Projects Office
E-Mail Address: cbcannon@lbl.gov

Enclosures: SOW and Budget

cc: W.T. Stringfellow, w/o enclosures
A. Bell, w/o enclosures
Chron
File

ADMINISTRATIVE INSTRUCTIONS TO OTHER FEDERAL AGENCIES FOR SUBMISSION OF INTERAGENCY AGREEMENTS FOR REIMBURSABLE WORK

Funding documents submitted to the Ernest O. Lawrence Berkeley National Laboratory (LBNL) for acceptance by the Department of Energy (DOE) should be signed by an individual in the requesting agency authorized to approve interagency agreements (IA). DOE accepts the IA format of the requesting agency which is normally a funding document such as a Department of Defense Military Interdepartmental Purchase Request (MIPR) that cites a separate document such as a LBNL proposal in which specific work to be performed is stated.

The <u>original</u> funding document should be issued and sent to:

U.S. Department of Energy
c/o Ernest O. Lawrence Berkeley National Laboratory
Sponsored Projects Office
Mail Stop 90-1070
Berkeley, CA 94720

All LBNL activities, including work for other Federal agencies, shall comply with applicable environment, safety, and health (ES&H) statutes, regulations and standards. Accordingly, ES&H requirements shall be considered during the planning phase and adhered to during execution of Work for Others (WFO). Associated costs will be the responsibility of the requesting agency.

LBNL is not permitted to incur costs before funding is authorized or in excess of authorized funding. Therefore, please forward your IA as soon as possible so that we may obtain DOE acceptance and begin work.

Funding documents submitted to LBNL for acceptance by DOE must contain the following information:

1. For all Federal agencies, other than the Nuclear Regulatory Commission, a written statement is required stating that the requesting agency has determined that entering into an agreement with DOE for the use of LBNL is in compliance with the requirements of the Economy Act of 1932, as amended (31 USC 1535) or other applicable statutory authorizations. Those statutory authorizations must be cited. In addition, a written statement is required stating that the requesting agency has determined that entering into an agreement with DOE for the use of LBNL is in compliance with the Federal Acquisition Regulation (FAR) 6.002, and to the best of their knowledge, the work requested will not place DOE and LBNL in direct competition with the private sector.

   <u>Sample Statement from a Federal Agency</u>

   "This agreement is entered into pursuant to the authority of the Economy Act of 1932, as amended (31 USC 1535), or other statutory authority references and adheres to Federal Acquisition Regulation (FAR) 6.002. To the best of our knowledge, the work requested will not place the DOE and its contractor in direct competition with the private sector."

2. Cite the proper customer agency appropriation. State funds expiration date for obligations. Provide name, mailing address, and telephone number of the requesting office. Provide names

and phone number of programmatic and financial points of contact. Provide billing information including office responsible for payment of bills.

3. Reference the LBNL proposal number and the title of the proposal. Provide funding document number of prior funding action if different than that being issued.

4. Cite reporting provisions as stated in the proposal as acceptable or state desired reporting requirements.

5. If the requesting agency plans on incremental funding, the reason full funding cannot be provided should be stated with a request for a DOE exception to DOE's full funding policy.

NOTE: DOE's policy is that work performed for other Federal agencies shall be fully funded for the current fiscal year plus the first three months of the following fiscal year for work that transcends fiscal years. Exceptions to the DOE full funding policy require approval by DOE prior to acceptance of the funding.

6. For construction or modifications to existing facilities which may be required as part of the project, the requesting agency shall include a request for construction and identify funding allocated for construction. DOE approvals associated with construction projects may take as long as three to six months to obtain. Title for permanent construction on DOE property will pass to DOE on completion of construction and acceptance by DOE.

7. If this is an award resulting from a response to a Broad Agency Announcement (BAA) or a similar type of solicitiation the requesting agency must provide a written statement that the BAA is the only means used to acquire the work descrtibed in the BAA.

8. The requesting agency should provide any special instructions regarding disposition of property at the close of the project.

9. Additional information about DOE's Work for Others program can be accessed via the internet. The address is http://www.hr.doe.gov/wfi/doe.htm#howto. The document is titled *How Federal Agencies Obtain Technical Resources and Skills from the U.S. D epartment of Energy.*

10/14/96

F1-305

JUL 28 1997

I. Executive Summary (2 pages)

a. Project Title and Applicant Name

Biological Metals Removal for the Treatment of Acid Mine Drainage in the Sacramento Valley.

William T. Stringfellow, Ph. D.
Environmental Engineer, Center for Environmental Biotechnology, MS 70A-3317, E. O. Lawrence Berkeley National Laboratory, Berkeley, CA 94720
Phone: (510) 486-6792, Fax: (510) 486-7152, e-mail: wstringfellow@lbl.gov

Karl E. Longley, Sc. D., P. E.
Dean, School of Engineering and Computer Science, 2320 East San Ramon Ave., M/S 94, California State University, Fresno, CA 93740-8028
Phone: (209) 278-2500, Fax: (209) 278-4475, e-mail: karll@csufresno.edu

Collaborators:

Phillip E. Heck. Ph. D., P. E.
Senior Engineer, Montgomery Watson, 4525 South Wasatch Blvd., Suite 200, Salt Lake City, UT 84124

H. Scott Mountford
Environmental Measurement Laboratory, E. O. Lawrence Berkeley National Laboratory, Berkeley, CA 94720

Lawrence P. Owens, Ph. D.
School of Engineering and Computer Science, 2320 East San Ramon Ave., M/S 94, California State University, Fresno, CA 93740-8028

b. Project Description and Primary Biological/Ecological Objectives

The primary biological/ecological objectives of this project are improvement of **chinook salmon** and **steelhead trout in-stream aquatic** habitat. Habitat for theses species have been reduced as a result of stream degradation due to uncontrolled **acid mine drainage (AMD)**. Development of a technology to treat AMD discharges and eliminate AMD production will have a direct benefit to chinook salmon and steelhead trout habitat.

It is possible to treat acidic waste streams using **sulfate reducing (SR) bacteria**, which consume sulfate, increase pH, and precipitate metals as insoluble sulfides. We are proposing a three year **development and demonstration project** to validate the use of a SR bacteria-based technology to **treat AMD** and to examine the potential for an SR bacterial process to **eliminate AMD production** in the mine itself.

c. Approach/Tasks/Schedules

The approach taken here follows the accepted model for the introduction of a novel technology into field application.

Task 1. Bench Scale Development. *Duration: 10 months, Year 1.* The first stage of the project will be to conduct laboratory studies which will include development of cultures, bench testing of different reactor configurations, comparison of different reducing substrates, selection of the most promising treatment alternative and determination of design parameters.

Task 2. Treatment Process Scale-up. *Duration: 5 months, Year 1; 5 months, Year 2.* After preliminary selection of the optimal reactor configuration and determination of design parameters (Task 1), the chosen process will be scaled to a mid-size reactor for further testing. At this stage, the robustness and efficiency of the process will be evaluated.

Task 3. Design and Construction Oversight of Pilot Plant Treatment Unit. *Duration: 2 months, Year 2.* In this stage of the project a pilot treatment study plan will be developed and a pilot treatment system will be designed using the data collected during Tasks 1 and 2.

Task 4. Pilot Plant Treatment Unit Construction. *Duration: 6 months, Year 2.* After completion of Task 3, the pilot treatment unit will be constructed at the mine site. The project will be competitively bid and a qualified contractor chosen. The unit will be tested at one of three mine sites: Greenborn, Afterthought, or **Iron Mountain**. Final selection of the test site will be made during the course of the first year of funding.

Task 5. Pilot Plant Treatment Unit Operation and Testing. *Duration: 10 months, Year 3.* After installation of the pilot treatment system at the mine site, the plant will be operated for not less than 9 months in the field. The plant will be operated using accepted engineering practices and evaluated for removal of metals, pH control, and sludge production. The success of the treatment will be evaluated based on the ability of the process to remove **cadmium, copper, lead,** and **zinc**; the amount and character of the sludge produced; the robustness and consistency of the process (ease of use); and the overall economy of the process. This evaluation will be made in comparison to lime precipitation, the currently accepted treatment technology.

Task 6. Laboratory and Field Research Support for Pilot Plant Treatment Unit Operation and Testing. *Duration: 5 months, Year 1; 12 months, Year 2; 10 months, Year 3.* In addition to the engineering parameters measured in the course of Tasks 3 and 5, samples will be taken for advanced biochemical, geochemical, and microbial analysis at the Center for Environmental Biotechnology. The properties and composition of the bacterial community in the reactor and the character of the sludge produced will be evaluated to fully document and understand the SR bacterial treatment process.

Task 7. Investigation of *In-Situ* Treatment Biotechnology. *Duration: 12 months, Year 2; 10 months, Year 3.* During the course of the second and third years of this project, bench scale research will be carried out to evaluate the potential for a SR bacteria based technology to eliminate AMD production in the mine. Model acid and metal producing systems will be treated with SR bacteria under a variety of process regimes and evaluated for their impact on **AMD production.** Successful regimes will be evaluated for applicability to full-scale, "down-shaft" treatment processes.

Task 8. Report Generation. *Duration: 1 month, Year 1; 1 month, Year 2; 3 months, Year 3.* Quarterly reports will be generated during the course of the project describing project progress and results. A final report will be generated in at the end of year three, encompassing all laboratory and field data.

d. Justification for Project and Funding by CALFED

This project addresses two CALFED Bay-Delta Program objectives: providing good **water quality** and **improvement of aquatic habitats.** This proposal is consistent with ERPP objectives concerning the **sustaining of diverse and valuable plant and animal species.** This project will directly and indirectly benefit Category III Priority Species **chinook salmon** and **steelhead trout** and Category III Priority Habitats **in-stream aquatic habitat** and **shaded riverine aquatic habitat**, all of which have been negatively impacted by acid and non-acid mine drainage containing heavy metals.

e. Budget Costs and Third Party Impacts

There are no apparent third party impacts from this proposal. **Task 1** is budgeted at $299,525 for Year 1; **Task 2:** $121,993 in Year 1 and $121,992 in Year 2; **Task 3:** $276,361 in Year 2; **Task 4:** $595,022 in Year 2; **Task 5:** $234,427 in Year 3; **Task 6:** $28,131 in Year 1, $465,144 in Year 2, $54,780 in Year 3; **Task 7:** $168,370 in Year 2 and $137,758 in Year 3; **Task 8:** $11,793 in Year 1, $11,793 in Year 2 $35,377 in Year 3. This gives budgets of $490,867 for Year 1, $1,249,430 for Year 2, and $422,170 for Year 3.

f. Applicant Qualifications

Dr. William T. Stringfellow is an Environmental Engineer at LBNL with over 13 years experience in bioprocess development and the treatment of concentrated industrial waste-streams. Dr. Karl E. Longley is Dean of the School of Engineering and Computer Science at CSUF, a Registered Professional Engineer, and a recognized authority in industrial waste-treatment and California water quality issues.

g. Monitoring and data evaluation

All data collection and evaluation will be conducted according to Cal-EPA QC requirements and accepted practices. All results, analysis, and conclusions will be subject to technical review by the collaborators, LBNL internal review, and open publication of the results.

h. Local Support/Coordination with other Programs/Compatibility with CALFED objectives

This project will be coordinated with Local, State and Federal regulatory agencies, mine site owners, and other responsible parties. Compatibility with CALFED objectives has been discussed in *I.d.* above.

II. *Title Page (1 page)*

a. *Title of Project*

Biological Metals Removal for the Treatment of Acid Mine Drainage in the Sacramento Valley.

b. *Name of Applicant*

William T. Stringfellow, Ph.D.
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c. *Type of Organization and Tax status*

National Laboratory and State University. Tax exempt.

d. *Tax ID number*

94-2951741

f. *Technical and Financial Contact persons*

Lawrence Berkeley National Laboratory:

Technical Contact: William T. Stringfellow, Phone: (510) 486-6792, Fax: (510) 486-7152.

Financial Contact: André Bell, Phone: (510) 486-6760, Fax: (510) 486-7714.

California State University, Fresno:

Karl E. Longley, Phone: (209) 278-2500, Fax: (209) 278-4475.

g. *Participants/Collaborators in Implementation*

Phillip E. Heck. Ph. D., P. E.
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h. *RFP Project Group Type(s):*
Group 3: Services

III. Project Description (6 pages)

a. Project Description and Approach

Acid mine drainage has a well documented negative impact on habitats associated with the Sacramento River. In the Sacramento Valley region, at both large and small mines, there is a near term need for a new technology to replace lime precipitation in the treatment of **acid mine drainage (AMD)**. There is also a clear long term need to develop a technology that will eliminate AMD production in the mine. New treatment techniques, based on the application of **sulfate-reducing (SR) bacteria** to remove metals from wastewater, are widely viewed as being more effective and less expensive than lime precipitation (Gusek 1995). There is a need to develop these techniques into a practical technology for the treatment of AMD in California.

We are proposing to develop and demonstrate a biological treatment process which uses SR bacteria to treat AMD. We will conduct a demonstration project that will allow evaluation of the economics and practically of the process under field conditions unique to California. The SR bacterial process will utilize the natural bacterial transformation of sulfate to sulfide, which will neutralize the AMD and simultaneously precipitate metals from solution as insoluble metal sulfides. This process is driven by the addition of a reducing substrate for consumption by the SR bacteria. We are also proposing to conduct research investigating the potential for this technology to eliminate the formation of AMD in the mine.

The approach taken here will follow the accepted model for the introduction of a novel technology into field application. This project will build upon previous work that has demonstrated the utility of SR bacteria for the treatment of high strength industrial waste streams containing sulfate and heavy metals (Dvorak et al 1992, Maree and Strydom 1987, Maree et al. 1986, Stucki et al. 1993). The project will begin at the bench level (Task 1), where the biological conditions necessary for the microbial reactions to take place will be defined in laboratories at Lawrence Berkeley National Laboratory. Various reducing substrates (e. g. sugars) for the bacteria will be tested and the optimal substrate chosen, based on cost, efficiency, and ease of use. The efficiency of the process under optimal conditions will be determined. The information gathered at the bench level will then be tested at a more realistic scale (Task 2) at research facilities at CSU, Fresno to work out mechanical problems and process design questions that can not be resolved at the bench level. After scale up, the pilot unit will be designed (Task 3) and constructed (Task 4). The pilot unit will then be operated at the mine site (either Iron Mountain, Afterthought, or Greenhorn mines) to validate the utility of this technology under field conditions (Tasks 5 and 6). Additionally, information gathered in Tasks 1 and 2 will be utilized in a research program (Task 7) examining the applicability of the anaerobic process to the actual elimination of AMD formation.

b. Location and Geographic Boundaries of the Project

The location of the project test sites are in Shasta County and impact tributaries of the Sacramento River. Technology developed in this project would benefit stream habitat in El Dorado, Placer, Nevada, Sierra, Yuba, Butte, Plumas, Lassen, Shasta, Tehama, Glenn, Lake, Colusa, Yolo, and Napa Counties.

c. Expected Benefits

Even with current treatment at Iron Mountain and other major mine sites, inactive mines in the Sacramento Valley contribute over 1,800 kg/year of **cadmium**, 63,900 kg/year of **copper**, 1,200 kg/year of **nickel**, 261,000 kg/year of **zinc**, and 500 kg/year of **lead** to the Sacramento drainage (Montoya and Pan 1992). Failure to control AMD has put an increased metals burden on the Bay and Delta regions. **Mine drainage** is a recognized Stressor under the **Increased Contaminants** Sub-category of the **Water Quality** Stressor Category (CALFED 1997). Heavy metals from mine drainage in Shasta County have been shown to negatively impact **chinook salmon**, **steelhead trout** and related species (Cacela et al. 1996, Finlayson and Verrue 1982, Finlayson and Wilson 1989, Finlayson and Wilson 1979). Metals from abandon mines continues to enter **sensitive in-stream** and **shaded riverine aquatic habitats** and can accumulate to toxic concentrations in sediments (Fujimura et al. 1995, Montoya and Pan 1992).

The application of the technology developed in this project will result in **significant reductions in toxic metal discharges** from inactive mines in the Sacramento River watershed. This technology will be developed as a less expensive alternative to lime precipitation for both small and large mine owners, encouraging compliance. The research concerning an *in-situ* treatment technology (Task 7) has the potential to lead to a true resolution to the AMD problem plaguing Northern California

d. Background and Biological/Technical Justification

Uncontrolled drainage from inactive mines in the Sacramento Valley presents a significant risk to the water quality of the Sacramento River Drainage Basin. There are over 90 inactive mines in the Sacramento Valley (Montoya and Pan 1992). Many of these mines discharge drain water characterized by low pH, high sulfate content, and high metal content. Mine drainage has been shown to be responsible for contributing the bulk of the copper, cadmium and zinc loads of the Sacramento River. The Sacramento River has periodically exceeded Inland Surface Water Plan (ISWP) objectives for copper, cadmium, and zinc (Montoya and Pan 1992). Exceedance of ISWP objectives has a negative impact on chinook salmon and steelhead trout (Finlayson and Wilson 1989, Finlayson and Verrue 1982, Montoya and Pan 1992).

The majority of inactive mines do not yet treat their AMD (Montoya and Pan 1992, Pedri 1997). California Judges have been reluctant to enforce environmental fines against smaller, out-of-compliance mine owners in the absence of an affordable treatment technology (Montoya and Pan 1992). However, under current enforcement actions, mine owners will soon be required to reduce AMD flow by 99% or to meet USEPA Best Available Technology (BAT) treatment standards for metals (Pedri 1997). Currently, treatment options for mine owners are limited.

BAT treatment standards for metals are based on lime treatment technology (Pedri 1997). Lime precipitation is an expensive process (Gusek 1995). Historically, lime treatment has been practiced only by large polluters, such as Iron Mountain Mine, which is legally required to control the release of copper, cadmium, zinc, and lead (EPA 1996). Although the lime precipitation process is able to remove metals from the mine drainage, a byproduct of lime precipitation is the generation of large amounts of sludge contaminated with dilute amounts of toxic metals. Currently, Iron Mountain Mine produces between 80 and 200 cubic yards of sludge per day, which is disposed of on site. On-site land disposal space is expected to last only 40 years, after which off-site disposal will be necessary (Cogliati 1997).

We are proposing to develop an anaerobic biological treatment process as an alternative technology to lime precipitation for metals removal from AMD. This technology utilizes a natural biological process for the fixation of metals. In this process, anaerobic sulfate reducing (SR) bacteria are used to convert sulfate to sulfide and the sulfide is reacted with the metals in solution to produce insoluble metal sulfides. Sulfide is a reactive species that combines rapidly with divalent metal cations to form highly insoluble metal sulfides (Stumm and Morgan 1996). As an additional benefit, bacterial sulfate reduction results in an increase in the aqueous pH.

The principles behind using SR bacteria for the biological treatment of mine drainage are well established (Dvorak et al 1992, Maree and Strydom 1987, Maree et al. 1986, Stucki et al. 1993). This process is driven by the addition of a reducing substrate (typically whey, a dairy industry waste product, or molasses) utilized by the SR bacteria as an energy source. Figure 1 illustrates the processes involved in the biological production of sulfide. There are a number of different types of SR bacteria are capable of converting sulfate to sulfide when provided with a reducing substrate (Widdel and Pfennig 1984). In an engineered biological treatment process, the reducing substrate is added to the waste stream and then reacted with the SR bacteria under controlled conditions that can be optimized for the removal of metals from the waste stream.

Biological treatment of acid mine drainage has been demonstrated at the bench level for coal mine drainage, copper-zinc mine drainage, and process water from a platinum mine (Maree and Strydom 1987, Christensen et al. 1996, Dvorak et al 1992). Anaerobic treatment has also been successfully applied to the treatment of high sulfate industrial wastes, including the destruction of sulfuric acid wastes (Maree et al. 1986, Stucki et al. 1993). It is reported that commercial scale anaerobic treatment unit has been built in the Netherlands for the treatment of metal and sulfate contaminated groundwater (Christensen et al. 1996).

Computer modeling was conducted at Lawrence Berkeley National Laboratory to determine how biological treatment would compare to lime precipitation in Iron Mountain Mine AMD. Modeling was conducted using average values for AMD entering the Iron Mountain Mine lime treatment plant in 1984 and 1985. The results of this analysis (Figure 2) show that anaerobic biological treatment has the potential to remove greater amounts of soluble metals with less pH adjustment than required for lime precipitation. In addition, the amount of sludge produced will be of less volume and of higher metals concentration than that produced during lime precipitation. This project will determine actual sludge production rates using biological treatment and determine if the metal content of the sludge will be high enough to warrant metal recovery.

Currently, there is no *in-situ* treatment technology that will stop acid production in the mine. An *in-situ* treatment that stopped AMD formation would preclude the need for surface treatment and maintain the ore value for the property owner. Plugging portals with concrete has been successful at stopping AMD out-falls in some cases, but plugging only works under specific geological conditions and often the plug is compromised by the exiting of the AMD through geological irregularities at higher levels than the plug. With plugging, the acid production in the mine may continue, resulting in groundwater contamination and a continued decrease in the value of the ore body (Pedri 1997).

Results from new studies have suggested that bioremediation using SR bacteria may be a viable option for eliminating AMD production and treating AMD contaminated groundwater (Christensen et al. 1996, Bottrell et al. 1995). It has been shown that SR bacterial activity will increase the pH of AMD, inhibiting the metal leaching activity of acid-loving bacteria (Christensen et al. 1996). It is our hypothesis that the process could be applied on a larger scale by the addition of substrates and a mixed SR bacterial culture directly into the mine. The addition of bacterial substrates will also drive oxygen from the system, creating conditions favorable for the SR bacteria and unfavorable for the metal leaching bacteria. In this way it may be possible to inhibit AMD production altogether. In this process, metals will redeposit as sulfide ores and be retained in the mine. Many question must be answered before this concept can be developed into an applicable technology. Task 7 will examine this promising technology in terms of it's fundamental soundness and practical application. Questions regarding potential reducing substrates, bacteria dosages, the mixed culture composition needed to optimize the process, and the influence of adverse environmental conditions will be addressed in this research. It is expected that at the completion of Task 7 we will be able to determine if this technology has potential for application as a permanent solution to the AMD problem in California.

Although the promise of anaerobic biological treatment for mine drainage is clear, the optimal design configuration for a full scale treatment process has not been fully evaluated. It is the objective of this proposal to investigate the potential for using anaerobic sulfate-reduction to treat mine drainage in the Sacramento Valley. The project is proposed for a three year period. In the first and second year, various design configurations will be tested for their efficacy for treating acid mine drainage. In the last year, a pilot scale plant will be constructed and used for a demonstration project to show the efficacy of anaerobic biological treatment under "real-world" conditions. We are also proposing to investigate the utilization of SR bacteria in a down-shaft treatment at the bench level (Task 7).

e. Proposed Scope of work

Task 1. Bench Scale Development. *Duration: 10 months, Year 1.* The first stage of the project will be to conduct laboratory studies which will include development of cultures, bench testing of different reactor configurations, comparison of different reducing substrates, selection of the most promising treatment alternative and determination of design parameters. Many different organisms are capable of reducing sulfate and producing sulfide anaerobically (Widdel and Pfennig 1984). Due to the high salt content typical of AMD, marine SR bacteria will be enriched from marine sediments for this project. An active SR bacteria mixed culture will be maintained in the laboratory and used in the described experiments. To develop the biochemical constants necessary for treatment plant design, the bacteria will be grown with AMD for measurement of growth rate, growth yield (sludge production), and substrate utilization rate. The pH and metal toxicity limits of the SR bacteria will be determined. Different potential reactor configurations (e. g. fixed film vs. suspended growth, up-flow vs. completely mixed) will be compared for their ability to tolerate variable flows, pH excursions, and metal removal efficiency. It is hypothesized at this point that an up-flow anaerobic sludge-blanket reactor (UASBR) will be the best design for this process. UASBR combine the stability advantages of a fixed film with the solids removal capabilities of a full mixed reactor (Metcalf and Eddy 1991). The use of an UASBR has been considered in the planning process, but costing and effort plans are also applicable to other biological treatment processes as well.

This work will be conducted under the direction of Dr. Stringfellow at Lawrence Berkeley National Laboratory (LBNL). Experiments will be designed jointly by Drs. Stringfellow, Longley, Owen, and Heck. Metal samples will be analyzed under the direction of Mr. Mountford at the LBNL Environmental Measurement Laboratory. Technical evaluation of experimental results will be will be provided by Dr. Stringfellow, Longley, Owen, and Heck.

Task 2. Treatment Process Scale-up. *Duration: 5 months, Year 1; 5 months, Year 2.* After selection of the optimal reactor configuration and determination of design parameters (Task 1), the chosen process will be scaled to a mid-size reactor for further testing. At this stage, the robustness and efficiency of the process will be evaluated at a larger, and therefore, more realistic scale.

Design and construction of this reactor is estimated to be completed within a period of three months, and the operation of the reactor will require an additional seven months to thoroughly evaluate process kinetics with the selected substrate.

Tentatively, an up-flow anaerobic sludge-blanket reactor (UASBR) will be designed with an up-flow velocity of 2 feet per hour and a 6 hour nominal detention time. The hydraulic characteristics of this reactor will be determined by dye testing prior to the initiation of the treatment process phase. A reactor diameter of 4 inches results in an AMD flow rate of 85.0 mL/min (0.0225 gal/min). The ratio of the flow rate of 5.0 gal/min for field scale plant to that for the pilot plant is 223 to 1. The determination of the organic loading rate range to be evaluated and the substrate to be used will initially be estimated during bench trials.

Two UASBR reactors will be constructed for comparing operations under different loading conditions. Each will have the AMD feed metered into the bottom of the reactor. The substrate, prepared as a liquid slurry, will be fed into the AMD feed line together with the pH adjustment feed prior to entry of the AMD stream to the reactor in order to insure good dispersion of the substrate throughout the AMD feed stream. The amount of pH adjustment that will be required will be initially determined during the initial bench tests.

Three metered feed pumps will be required, one for the AMD stream and one for the substrate slurry. The USABR reactors, all piping, the pumps, and all ancillary equipment will be constructed from approved materials inert to the corrosiveness of AMD and sulfide. The top of the reactors will be outfitted for gas collection so that the rate of substrate utilization can be estimated and gas composition can be determined.

Sludge will periodically be removed from the bottom of the USABR reactors by draining to a batch, unmixed reactor vessel where the sludge will be allowed to settle and will then be de-watered. All sludge produced during both pilot and field evaluation will be disposed of in compliance with all applicable codes and regulations. No treated water will be discharged to the environment that does not meet the applicable state and federal water quality guidelines.

Operation of the UASBR reactors will proceed throughout the seven month operation period for the purpose of further determining optimal substrate feed rates and reactor detention times necessary to yield satisfactory metals reduction. This data will be used for the design of the larger reactors at the field site. The technology will then be field tested for a period of ten months during which time it will be subjected to seasonal factors.

This work will be conducted at California State University, Fresno under the direction of Dr. Longley. The pilot reactor will be designed jointly by Drs. Stringfellow, Longley, Owens, and Heck. The reactor will be constructed and tested under the direction of Drs. Longley and Owens. Analyses will be carried out at the treatment unit site for operational parameters and metals removal. To maintain quality control, some samples for metal analysis will split at CSUF and shipped to LBNL for analysis under the direction of Mr. Mountford at the Environmental Measurement Laboratory. Technical evaluation of results will be provided by Drs. Stringfellow, Longley, Owens, and Heck.

I-006619

Task 3. Design of Pilot Plant Treatment Unit. *Duration: 2 months, Year 2.* In this stage of the project a pilot study plan would be developed and a pilot treatment system would be designed using the data collected during Tasks 1 and 2.

Dr. Heck will write a scope of work for bidding the pilot reactor design. The scope of work will be reviewed by Drs. Stringfellow, Longley, and Owens. Cost estimates for the design subcontract are based on prior experience with other pilot treatment system having a flow rate in the range of 10 to 30 gpm (Figure 3). The design would include development of process and instrumentation diagrams (P&IDs), facility and piping layouts, electrical and control system plans, equipment selection and sizing and a construction cost estimate. If necessary, the design will also provide structural design of any foundations or buildings required to support/house the treatment system.

Task 4. Pilot Plant Treatment Unit Construction. *Duration: 6 months, Year 2.* After completion of Task 3, the pilot treatment unit will be constructed. The unit will be tested at one of three mine sites: Greenhorn, Afterthought, or Iron Mountain.

Iron Mountain Mine is the preferred site because the AMD is well characterized, seasonal flow variations are well documented, the site has security, utilities and paved road access, and the site is manned by a very professional and experienced staff. Most importantly, Iron Mountain Mine has a full scale lime treatment process in place that will allow direct comparison between the biological process and the accepted practice of lime precipitation.

Task 4 will be competitively bid and then a qualified contractor chosen. The exact costs for the pilot unit can only be estimated until Task 3 is completed and the test site finalized. Cost estimates for the construction are based on prior experience (Figure 3). Using Iron Mountain Mine as the test site will allow a considerable cost savings in infrastructure development. Drs. Heck, Longley, and Stringfellow will take the lead in management of Task 4.

Task 5. Pilot Plant Treatment Unit Operation and Testing. *Duration: 10 months, Year 3.* After installation of the pilot treatment system at the mine site, the plant will be operated for not less than 9 months in the field. The plant will be operated using accepted engineering practices and evaluated for removal of metals, pH control, and sludge production. Operational parameters (e. g. sludge age, hydraulic loading) controlling the biological process will be measured, documented, and evaluated on an ongoing basis. The success of the treatment will be evaluated based on the ability of the process to remove cadmium, copper, lead, and zinc; the amount and character of the sludge produced; the robustness and consistency of the process (ease of use); and the overall economy of the process. This evaluation will be made in comparison to lime precipitation, the currently accepted treatment technology.

This work will be conducted under the joint direction of Drs. Stringfellow and Longley. Data collection and engineering analysis will be designed jointly by Drs. Stringfellow, Longley, Owen, and Heck. Samples for metal analysis will be collected by a qualified technician and shipped to LBNL for analysis under the direction of Mr. Mountford at the LBNL Environmental Measurement Laboratory. Technical evaluation of experimental results will be will be provided by Dr. Stringfellow, Longley, Owen, and Heck.

Task 6. Laboratory and Field Research Support for Pilot Plant Treatment Unit Operation and Testing. *Duration: 12 months, Year 2; 10 months, Year 3.* In addition to the engineering parameters measured in the course of Tasks 2 and 5, samples will be taken for advanced biochemical, geochemical, and microbial analysis at the Center for Environmental Biotechnology. The properties and composition of the bacterial community in the reactor will be evaluated to fully document and understand the SR bacterial treatment process. The geochemical composition and physical properties of the sludge will be evaluated using standard engineering tests and advanced techniques such as scanning x-ray and infra-red microprobes available at LBNL. This task will be managed by Dr. Stringfellow.

Task 7. Investigation of *In-Situ* Treatment Biotechnology. *Duration: 12 months, Year 2; 10 months, Year 3.* During the course of the second and third years of this project, bench scale research will be carried out to evaluate the potential for a SR bacteria based technology to eliminate AMD production in the mine. Model acid and metal producing systems will be treated with SR bacteria under a variety of process regimes and evaluated for their impact on AMD production. Successful regimes will be evaluated for applicability to full-scale, "down-shaft" treatment processes.

Experiments will be conducted to determine the minimum dosage of SR bacteria and reducing substrates that will be required to drive the process forward under the adverse conditions typically found in acid producing mines. Inexpensive carbon sources, including paper waste and composted sludge, will be examined for their efficiency as a source of reducing energy for the SR bacteria. The potential for negative impacts from the application of this process *in situ* will be examined. The applicability of using the SR bacteria as a "living plug," in which SR bacterial biofilms can be grown in the adits to treat the AMD as it exits the mine works, will be tested in flow through systems modeled to imitate the conditions found in the field.

These experiments will be conducted at Lawrence Berkeley National Laboratory under the direction of Dr. Stringfellow. Experiments will be designed in collaboration with Drs. Longley and Heck.

Task 8. Report Generation. *Duration: 1 month, Year 1; 1 month, Year 2; 3 months, Year 3.* Quarterly reports will be generated during the course of the project describing project progress and results. A final report will be generated in at the end of year three, encompassing all laboratory and field data. The final report will include data analysis and conclusions concerning the SR bacterial process. Recommendations for implementation of the treatment system at large and small mines, with perennial or seasonal flows, will be made. Results and recommendations concerning the feasibility of *in-situ* treatment to prevent AMD formation will be made.

Drs. Longley and Stringfellow will be responsible for generating reports.

f. Monitoring and Data evaluation.

All results, analysis, and conclusions will be subject to technical review by the collaborators, LBNL internal review, and open publication of the results. QA/QC protocols will be reviewed and approved by Mr. Mountford. All samples and pilot data will be collected and analyzed according to California EPA and USEPA standards and protocols. Metals contents of water and sludge samples will be analyzed by EPA methods 6010, 6020, 3050A, and 3010 in a California Department of Health Services and US Navy certified laboratory at Lawrence Berkeley National Laboratory under the direction of Mr. Mountford. All data collection and evaluation will be conducted according to Cal-EPA QC requirements and accepted practices. Financial oversight will be provided by both LBNL and CSUF.

g Implementability

This project is impementable as it now stands. This project will comply with all applicable laws and regulations. This project has been discussed with, and will continue to be coordinated with, the California Regional Water Quality Control Board, the USEPA, Stauffer Management Company, and other parties interested in finding resolutions to the problem of Iron Mountain Mine and AMD in the Sacramento Valley.

The site for placement of the pilot unit remains to be selected. Iron Mountain Mine is our preferred test site (as discussed above) and will yield in cost saving during Tasks 4 and 5. Negotiations are currently in progress with Stauffer Management Company and other interested parties at Iron Mountain Mine to gain access to that site. Owners of the other sites currently under consideration have expressed their interest in serving as test sites. Final negotiations to determine the test site will be completed during the first funded year of the project.

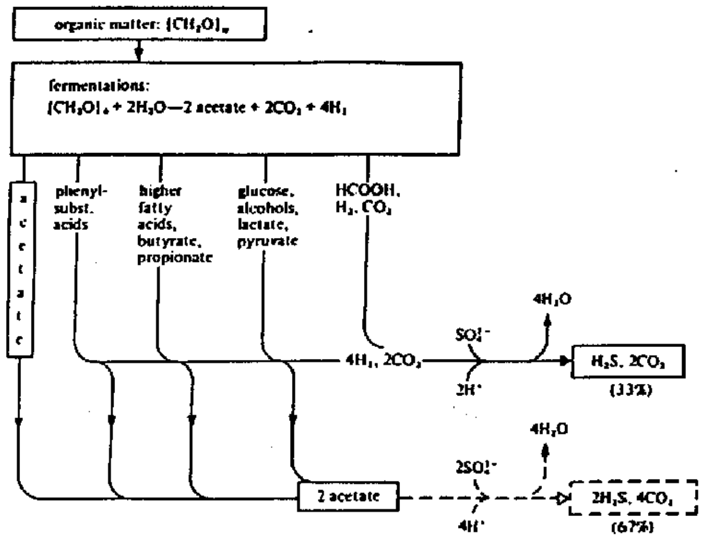

FIGURE 1. Scheme of the anaerobic degradation of organic matter by fermentations and different pathways of subsequent oxidation linked to sulphate reduction.

Figure 2: Potential for the improved removal of toxic metal ions from Iron Mountain Mine drainage water using anaerobic biological treatment. Lines represent the maximum solubility of heavy metals in the effluent of a lime precipitation plant (pH adjustment only) versus biological sulfide precipitation (with sulfide).

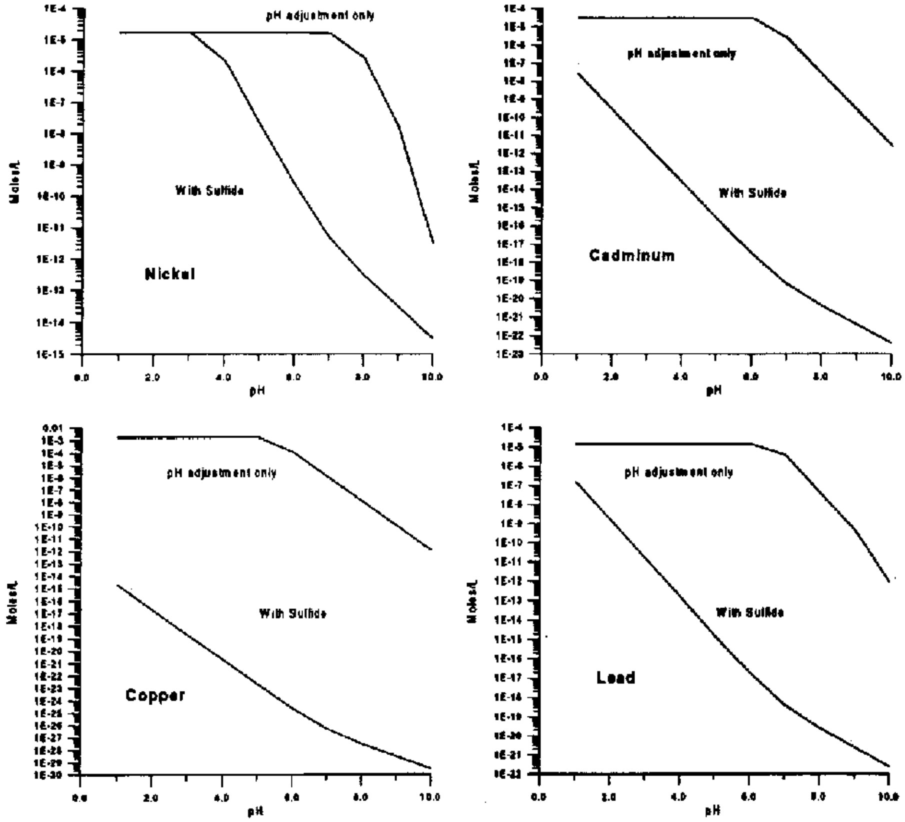

Figure 3:

MONTGOMERY WATSON

July 23, 1997

Dr. William T. Stringfellow
Center for Environmental Biotechnology
Lawrence Berkeley National Laboratory
M.S. 70A-3317
Berkeley, CA 94720
(510) 486-7903

SUBJECT: Estimated Costs for Acid Mine Drainage Pilot Treatment System

Dear Will:

To complete the pilot scale demonstration project at a scale that is large enough to provide data representative of full scale treatment systems, I would recommend a flow capacity in the range of 10 to 30 gallons per minute. This is a reasonably large scale project and would require significant design prior to the actual construction. During the design phase, process and instrumentation diagrams (P&IDs), process control sequence, facility and piping layouts, electrical and control system plans, equipment selection and sizing, and a construction cost estimate would need to be completed. Depending on site conditions, it may also be necessary to design foundations or a small building to support/house the treatment system. During the construction phase a general contractor would need to be hired. The contractor would procure the equipment, hire any subcontractors (mechanical, electrical, instrumentation and controls), and manage the construction of the treatment system.

The costs for the design and construction phases of the project are difficult to determine at this stage because the system and the site are undefined. However, I can provide you with a general idea of the magnitude of the costs based on projects of similar scale that we have recently completed. The first project was a 25 gpm pilot treatment system for groundwater contaminated with TNT and RDX that we designed and built for the U.S. Army. The system consisted of a concrete containment pad, six stainless steel reactors, piping and pumping systems, chemical feed systems, ozone generation and off-gas destruct systems (rented), GAC system (rented), and electrical and controls system. The cost for the design phase was about $230,000 and the construction was about $420,000. The second project was a groundwater treatment system at a Superfund Site that treats 30 gpm. The system consisted of a metal building, metals precipitation system, clarifier, sand filter, equipment platform, air stripper, GAC, sludge storage, sludge dewatering, piping and pumps, compressed air, chemical feed systems, electrical and instrumentation systems, and a computer control system. The design costs were about $200,000 and the construction costs were about $600,000, not including the building.

Based on my experience, I think a reasonable range to used for estimating the costs for a pilot treatment system of the scale you are considering is $400,000 to $750,000. If you need any further information or have any questions please give me a call.

Sincerely,

MONTGOMERY WATSON

Phil Heck

Phillip E. Heck, Ph.D., P.E.

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Suite 200
Salt Lake City, Utah
84124-4799

Tel: 801 272 1900
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Table 1: References.

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IV. Costs and Schedule to Implement Proposed Project (2pgs + Table and figures)

a. Budget Costs

The budgets for the total project, each task, and for each partner are explained in the following tables. Table 2 presents the overall budget by Task. Table 3 (3 pages) presents the detailed LBNL budget by year. Table 4 presents the detailed LBNL budget by Task. Table 5 presents the detailed CSUF budget by year. Table 6 presents the detailed CSFU budget by Task. Table 7 presents the Montgomery Watson budget by Task.

This project will be supported by CALFED funding only. Application is being made to waive DOE Added Factor costs. Individual project Tasks are organized for incremental funding as requested in the RFP.

b. Schedule Milestones

See below (after budget tables).

c. Third Party Impacts

This project does not have any known negative third party impacts.

Table 2: Overall Budget by Task.

LBNL	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	TOTALS
Stringfellow	$98,012	$7,001	$7,225	$41,351	$54,605	$54,605	$129,307	$43,895	$436,001
Castro	$67,207				$77,467	$41,351	$77,585	$0	$263,610
Mountford	$22,916	$5,913			$17,293	$11,375	$11,824	$0	$69,321
GSRA	$42,909					$27,600	$53,925	$0	$124,434
Salary and Benefits	$231,044	$12,914	$7,225	$41,351	$149,365	$134,931	$272,641	$43,895	$893,366
Supplies	$14,039	$1,466			$14,039	$7,020	$19,656		$56,220
Travel	$3,630	$3,630		$1,210	$3,630		$1,210		$13,310
Subcontracts	$10,007	$6,152	$233,241	$515,680	$21,832			$2,591	$789,503
4.3% DOE-AF	$11,125	$1,039	$10,340	$24,004	$8,121	$6,104	$12,621	$1,999	$75,353
LBNL TOTAL	**$269,845**	**$25,201**	**$250,806**	**$582,245**	**$196,987**	**$148,055**	**$306,128**	**$48,485**	**$1,827,752**

CSUF	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	TOTALS
K. Longley	$9,800	$12,000	$8,400	$4,200	$12,000			$4,000	$50,400
Process Fabricator		$5,000							$5,000
Associate Project Officer	$3,150	$4,500	$2,700	$1,350	$4,000			$500	$16,200
Process Operator(s)		$36,000							$36,000
Secretary/Data Entry		$5,040							$5,040
Secretary/Data Entry	$2,100	$2,500	$1,800	$900	$2,500			$1,000	$10,800
Personnel Benefits,	$5,268	$22,764	$4,515	$2,258	$6,475			$1,925	$43,204
Chemical Analysis (Pilot)		$32,400							$32,400
AMD Transport		$42,000							$42,000
Materials		$12,000							$12,000
Tanks		$3,000							$3,000
pH Controllor		$5,300							$5,300
Travel	$1,000	$1,500	$1,000	$500	$2,000				$6,000
Tele., Computer & FAX	$500	$800	$400	$200	$800			$180	$2,880
CSUF Foundation, Overhead	$7,863	$33,980	$6,740	$3,370	$9,665			$2,873	$64,491
CSUF TOTAL	**$29,680**	**$218,784**	**$25,555**	**$12,777**	**$37,440**			**$10,478**	**$334,715**
Project TOTAL	**$299,525**	**$243,985**	**$276,361**	**$595,023**	**$234,428**	**$148,055**	**$306,128**	**$58,963**	**$2,162,467**

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Table 3: LBNL Budgets by Year

LBNL PROPOSAL BUDGET ESTIMATE FY 1998		FY98		
	Effort			Total
SALARIES AND WAGES	[Effort unit]	Rate	Est Cost	Cost
Stringfellow	10.5	$6,798	$71,379	
Castro	10.5	$4,079	$42,827	
Mountford	2	$5,563	$11,126	
GSRA	7.5	$2,575	$19,313	
TOTAL Labor	30.5			$144,645
FRINGE BENEFITS	Rate	Base	Est Cost	
B.1 Scientific/Career (A.1 div 1.20)	0.214	$125,332	$22,351	
B.2 GSRA	0.23	$19,313	$3,702	
TOTAL Fringe Benefits				$26,053
TOTAL SALARIES AND FRINGE BENEFITS				$170,698
SCIENTIFIC AND SUPPORT BURDEN				
D.1 Scientific Burden (on C – A.X)	0.165	$170,698	$28,165	
D.2 Support Burden (on A.X)	0		$0	
TOTAL Scientific/Support Burden				$28,165
SUBCONTRACTS, CONSULTANTS, & OTHER SERVICES				$11,748
PURCHASES				
F.1 Equipment		$0		
F.2 Other procurements; lab & office supplies		$13,000		
F.3 Procurement burden/material handling		$2,178		
TOTAL Purchases				$15,178
TRAVEL				
G.1 Domestic		$3,500		
G.2 Foreign		$0		
TOTAL Travel				$3,500
TOTAL DIRECT COSTS and BURDENS (C thru J)				$229,288
OVERHEAD	Rate	Base	Est Cost	
L.1 Site Support (on C + D + F.3 + H + J)	0.24	$214,040	$51,370	
L.2 G&A (on C+D+F.3+G+H+J+L.1)	0.21	$253,733	$53,284	
TOTAL Overhead				$104,654
TOTAL LABORATORY COSTS (K+L)				$333,942
DEPRECIATION (11.7% of C; 5.2% of H.2)				
DOE-ADDED FACTOR (on Lines M+N)	0.043			$14,360
TOTAL COSTS (M+N+O)				**$348,302**

Table 3: LBNL Budgets by Year (Continued)

LBNL PROPOSAL BUDGET ESTIMATE FY 1999			FY99	
	Effort			Total
SALARIES AND WAGES	[Effort unit]	Rate	Est Cost	Cost
Stringfellow	10.5	$6,996	$73,458	
Castro	10.5	$4,198	$44,075	
Mountford	2	$5,725	$11,451	
GSRA	7.5	$2,650	$19,875	
TOTAL Labor	30.5			$148,859
FRINGE BENEFITS	Rate	Base	Est Cost	
B.1 Scientific/Career (A.1 div 1.20)	0.218	$128,984	$23,432	
B.2 GSRA	0.23	$19,875	$3,809	
TOTAL Fringe Benefits				$27,241
TOTAL SALARIES AND FRINGE BENEFITS				$176,100
SCIENTIFIC AND SUPPORT BURDEN				
D.1 Scientific Burden (on C – A.X)	0.165	$176,100	$29,057	
D.2 Support Burden (on A.X)	0		$0	
TOTAL Scientific/Support Burden				$29,057
SUBCONTRACTS, CONSULTANTS, & OTHER SERVICES				$648,311
PURCHASES				
F.1 Equipment		$0		
F.2 Other procurements; lab & office supplies		$13,500		
F.3 Procurement burden/material handling		$58,239		
TOTAL Purchases				$71,739
TRAVEL				
G.1 Domestic		$3,500		
G.2 Foreign		$0		
TOTAL Travel				$3,500
TOTAL DIRECT COSTS and BURDENS (C thru J)				$928,708
OVERHEAD	Rate	Base	Est Cost	
L.1 Site Support (on C + D + F.3 + H + J)	0.24	$276,897	$66,455	
L.2 G&A (on C+D+F.3+G+H+J+L.1)	0.21	$275,112	$57,774	
TOTAL Overhead				$124,229
TOTAL LABORATORY COSTS (K+L)				$1,052,937
DEPRECIATION (11.7% of C; 5.2% of H.2)				
DOE-ADDED FACTOR (on Lines M+N)	0.043			$45,276
TOTAL COSTS (M+N+O)				$1,098,213

Table 3: LBNL Budgets by Year (Continued)

LBNL PROPOSAL BUDGET ESTIMATE FY 2000	FY00			
SALARIES AND WAGES	Effort [Effort unit]	Rate	Est Cost	Total Cost
Stringfellow	10.5	$7,194	$75,537	
Castro	10.5	$4,316	$45,322	
Mountford	2	$5,887	$11,775	
GSRA	7.5	$2,725	$20,438	
TOTAL Labor	30.5			$153,072
FRINGE BENEFITS	Rate	Base	Est Cost	
B.1 Scientific/Career (A.1 div 1.20)	0.222	$132,634	$24,537	
B.2 GSRA	0.23	$20,438	$3,917	
TOTAL Fringe Benefits				$28,455
TOTAL SALARIES AND FRINGE BENEFITS				$181,527
SCIENTIFIC AND SUPPORT BURDEN				
D.1 Scientific Burden (on C – A.X)	0.165	$181,527	$29,952	
D.2 Support Burden (on A.X)	0		$0	
TOTAL Scientific/Support Burden				$29,952
SUBCONTRACTS, CONSULTANTS, & OTHER SERVICES				$21,933
PURCHASES				
F.1 Equipment		$0		
F.2 Other procurements; lab & office supplies		$13,500		
F.3 Procurement burden/material handling		$3,118		
TOTAL Purchases				$16,618
TRAVEL				
G.1 Domestic		$4,000		
G.2 Foreign		$0		
TOTAL Travel				$4,000
TOTAL DIRECT COSTS and BURDENS (C thru J)				$254,030
OVERHEAD	Rate	Base	Est Cost	
L.1 Site Support (on C + D + F.3 + H + J)	0.24	$228,097	$54,743	
L.2 G&A (on C+D+F.3+G+H+J+L.1)	0.21	$270,222	$56,747	
TOTAL Overhead				$111,490
TOTAL LABORATORY COSTS (K+L)				$365,520
DEPRECIATION (11.7% of C; 5.2% of H.2)				
DOE-ADDED FACTOR (on Lines M+N)	0.043			$15,717
TOTAL COSTS (M+N+O)				**$381,237**

Table 4: LBNL Budget by Task

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	TOTALS
Direct Labor Hours	**4350**	**174**	**87**	**522**	**2523**	**2610**	**5133**	**522**	**15921**
Stringfellow	$98,012	$7,001	$7,225	$41,351	$54,605	$54,605	$129,307	$43,895	$436,001
Castro	$67,207				$77,467	$41,351	$77,585	$0	$263,610
Mountford	$22,916	$5,913			$17,293	$11,375	$11,824	$0	$69,321
GSRA	$42,909					$27,600	$53,925	$0	$124,434
Salary and Benefits	**$231,044**	**$12,914**	**$7,225**	**$41,351**	**$149,365**	**$134,931**	**$272,641**	**$43,895**	**$893,366**
Supplies	$14,039	$1,466			$14,039	$7,020	$19,656		$56,220
Travel	$3,630	$3,630		$1,210	$3,630		$1,210		$13,310
Subcontracts	$10,007	$6,152	$233,241	$515,680	$21,832			$2,591	$789,503
Subtotal	**$258,720**	**$24,162**	**$240,466**	**$558,241**	**$188,866**	**$141,951**	**$293,507**	**$46,486**	**$1,752,399**
4.3% DOE-AF	$11,125	$1,039	$10,340	$24,004	$8,121	$6,104	$12,621	$1,999	$75,353
Total Costs	**$269,845**	**$25,201**	**$250,806**	**$582,245**	**$196,987**	**$148,055**	**$306,128**	**$48,485**	**$1,827,752**

Note: All amounts include Overheads: 16.5% Scientific Burden on Salaries & Benefits(avg 39.5%), 8.8% Procurement Burden on Purchases including subcontracts, 24% Site Support on Direct Costs, 21% G&A on Total Direct Costs & Burdens.

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Table 5: UCFS Budget by Year

			YEAR 1	YEAR 2	YEAR 3	TOTAL
Personnel						
K. Longley	20 hrs/mo for 3 yrs	70 /hr	17,133	19,933	13,333	50,400
Process Fabricator	250 hrs	20 /hr	2,500	2,500		5,000
Associate Project Officer	10 hrs/mo for 3 yrs	45 /hr	5,566	6,466	4,166	16,200
Process Operator(s)	48 hrs/wk for 30 weeks	25 /hr	18,000	18,000		36,000
Secretary/ Data Entry	8 hrs/wk for 42 weeks	15 /hr	2,520	2,520		5,040
Secretary/ Data Entry	20 hrs/mo for 3 yrs	15 /hr	3,683	4,283	2,833	10,800
Subtotal			49,403	53,703	20,333	123,440
Personnel Benefits,	0.35		17,291	18,796	7,116	43,204
Subtotal, Personnel			66,694	72,499	27,450	166,644
Process Control and Operation						
Chemical Analysis (Pilot)	6 hvy metal anal. 30 wks	180 ea	16,200	16,200		32,400
AMD Transport	2000 gal/mo for 7 mos	3 /gal	21,000	21,000		42,000
Subtotal, Process Control & Operation			37,200	37,200		74,400
Pilot Reactor Construction						
Materials	lump sum		6,000	6,000		12,000
Tanks	2 each @ 1500 gals	1500 /tank	1,500	1,500		3,000
pH Controller	1 each	5300 ea	2,650	2,650		5,300
Subtotal, Pilot Reactor Construction			10,150	10,150		20,300
Other						
Travel	lump sum		1,750	2,250	2,000	6,000
Tele., Computer & FAX	36 months	80 mo	960	1060	860	2880
Subtotal, Other			2,710	3,310	2,860	8,880
SUBTOTAL			116,754	123,159	30,310	270,224
CSUF Foundation, Overhead (38.7% of Salary & Wages)			25,810	28,057	10,623	64,491
TOTAL			142,565	15,1216	40,933	334,715

Table 6: UCFS Budget by Task

					TASK 1	TASK 2	TASK 3	TASK 4	TASK 5	TASK 8	TOTAL
Personnel											
K. Longley	20	hrs/mo for 3 yrs	$70 /hr	$50400	$9800	$12000	$8400	$4200	$12000	$4000	$50400
Process Fabricator	250	hrs	$20 /hr	$5000		$5000					$5000
Associate Project Officer	10	hrs/mo for 3 yrs	$45 /hr	$16200	$3150	$4500	$2700	$1350	$4000	$500	$16200
Process Operator(s)	48	hrs/wk for 30 weeks	$25 /hr	$36000		$36000					$36000
Secretary/Data Entry	8	hrs/wk for 42 weeks	$15 /hr	$5040		$5040					$5040
Secretary/Data Entry	20	hrs/mo for 3 yrs	$15 /hr	$10800	$2100	$2500	$1800	$900	$2500	$1000	$10800
Subtotal				$123440	$15050	$65040	$12900	$6450	$18500	$5500	$123440
Personnel Benefits,	35%			$43204	$5268	$22764	$4515	$2258	$6475	$1925	$43204
Subtotal, Personnel				$166644	$20318	$87804	$17415	$8708	$24975	$7425	$166644
Process Control and Operation											
Chemical Analysis (Pilot)	6	heavy metal anal. 30 wk	$180 ea	$32400		$32400					$32400
AMD Transport	2000	gal/ 7 mos	$3 /gal	$42000		$42000					$42000
Subtotal, Process Control & Operation				$74400		$74400					$74400
Pilot Reactor Construction											
Materials		lump sum		$12000		$12000					$12000
Tanks	2	1500 gals	$1500 ea	$3000		$3000					$3000
pH Controller	1	each	$5300 ea	$5300		$5300					$5300
Subtotal, Reactor Construction				$20300		$20300					$20300
Other											
Travel		lump sum		$6000	$1000	$1500	$1000	$500	$2000		$6000
Tele., Computer & FAX	36	months	$80 mo	$2880	$500	$800	$400	$200	$800	$180	$2880
Subtotal, Other				$8880	$1500	$2300	$1400	$700	$2800	$180	$8880
SUBTOTAL				$270224	$21818	$184804	$18815	$9408	$27775	$7605	$270224
CSUF Foundation, Overhead (38.7% of Salary & Wages)				$64491	$7863	$33980	$6740	$3370	$9665	$2873	$64491
TOTAL				$334715	$29680	$218784	$25555	$12777	$37440	$10478	$334715

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Table 7: Montgomery Watson Budget by Task

CLASSIFICATION 1997 Direct labor rate/hour:	Senior Engineer $100.00		Designer $60.00		Secretary/Word Processing. $45.00		TASK TOTAL	
Task Description	Hours	Amount	Hours	Amount	Hours	Amount	Hours	Amount
TASK 1 - Bench-Scale Development	80	$8,000			6	$270	86	$8,270
TASK 2 - Treatment Process Scale-up	50	$5,000			2	$90	52	$5,090
TASK 3 - Design	80	$8,000	10	$600	2	$90	92	$8,690
TASK 4 - Construction	140	$14,000	12	$720	2	$90	154	$14,810
TASK 5 - Operation	180	$18,000			2	$90	182	$18,090
TASK 6 - Research Support	0							
TASK 7 - In-Situ Treatment Investigation	0							
TASK 8 - Final Report	20	$2,000			3	$135	23	$2,135
SUBTOTAL	**550**	**$55,000**	**22**	**$1,320**	**17**	**$765**	**589**	**$57,085**

Other Direct Charges (ODCs)	Units	Price	Quantity	Total
Associated Project Costs (1)	Hourly	$8.33	589	$4,906
Total Other Direct Charges				**$4,906**
Total Project Labor and ODC Costs				**$61,991**

(1) Associated project expenses, including telecommunications (equipment, local and long distance charges), facsimile, computer and word processing equipment, first class postage, express mail letter packs (excludes boxes and courier service), network charges, and in-house reproduction and printing of plans, reports, and other documents (black & white, up to 11x17 inches, 5 copies) will be invoiced at $8.33 per total labor hour, in lieu of detailed invoicing of the specified items.

b. *Schedule Milestones*

Start and completion dates of specific tasks depends on the start date of funding. Assuming an October 1, 1997 start date, the project is designed on a 3 year (36 month) schedule as follows:

Year Month	Project Month	Task 1 Bench	Task 2 Scale-up	Task 3 Design	Task 4 Building	Task 5 Operate	Task 6 Lab Support	Task 7 *In-situ*	Task 8 Reports
10/97	1	X							
11/97	2	X							
12/97	3	X							
1/98	4	X							X
2/98	5	X							
3/98	6	X							
4/98	7	X							
5/98	8	X	X						X
6/98	9	X	X				X		
7/98	10	X	X				X		
8/98	11		X				X		
9/98	12		X				X		X
10/98	13		X				X	X	
11/98	14		X				X	X	
12/98	15		X				X	X	
1/99	16		X				X	X	X
2/99	17		X				X	X	
3/99	18			X			X	X	
4/99	19			X			X	X	
5/99	20				X		X	X	X
6/99	21				X		X	X	
7/99	22				X		X	X	
8/99	23				X		X	X	
10/99	24				X		X	X	X
11/99	25				X		X	X	
12/99	26					X	X	X	
1/00	27					X	X	X	
2/00	28					X	X	X	X
3/00	29					X	X	X	
4/00	30					X	X	X	
5/00	31					X	X	X	
6/00	32					X	X	X	X
7/00	33					X	X	X	
8/00	34					X	X		
9/00	35					X	X		
10/00	36								X

V. Applicant Qualifications (3pgs, including Tables)

William T. Stringfellow, Ph. D.
Environmental Engineer, Center for Environmental Biotechnology, MS 70A-3317, E. O. Lawrence Berkeley National Laboratory, Berkeley, CA 94720
Phone: (510) 486-6792, Fax: (510) 486-7152, e-mail: wstringfellow@lbl.gov

Dr. William T. Stringfellow is an Environmental Engineer at LBNL with over 13 years experience in bioprocess development and the biological treatment of concentrated industrial waste-streams. Dr. Stringfellow has a long-standing interest in the application of sulfur-cycling bacteria in environmental processes. In addition to a Ph.D. in Environmental Sciences and Engineering, Dr. Stringfellow has a Masters Degree in Microbiology and extensive experience as an industrial scientist researching the biological treatment of industrial wastes and consulting bioremediation projects in the United States and Europe.

Selected Publications, Patents, and Reports:

Grimberg, S. J., W. T. Stringfellow, and M. D. Aitken. 1996. Quantifying the biodegradation of phenanthrene by *Pseudomonas stutzeri* P16 in the presence of a nonionic surfactant. *Appl. Environ. Microbiol.* 62:2387-2392.

Stringfellow, W. T. and M. D. Aitken. 1995. Competitive metabolism of naphthalene, methylnaphthalenes, and fluorene by phenanthrene degrading bacteria. *Appl. Environ. Microbiol.* 61:357-362.

Stringfellow, W. T., N. R. Connell, C. F. Felin, and W. P. Coleman. 1988. Variables influencing sulfide concentration in a gravity flow collection system. *J. Water Pollution Control Fed.* 60: 2111 - 2114.

Stringfellow, W. T., C. D. Goldsmith, and L. T. Davis. Use of Bacteria for Control of Algal Bloom in Wastewater, Lagoons, or Ponds. May 6, 1988, Patent No. 07/191,073.

Stringfellow, W.T. Biological treatment of concentrated grease and septic wastes. Biokinetic analysis and recommendations for operation of a full scale disposal facility. 1989. Sybron Chimie France, S.A. and La Societe Francaise pour la Distribution d'Eau Joint Internal Report.

Stringfellow, W.T. Simple modeling of variables influencing sulfide concentration in the Worcester County collection system. 1988. Sybron Chemicals Inc. Internal Report.

Stringfellow, W.T. and W.P. Coleman. Field test of *Thiobacillus neapolitanus* at Worcester County, Maryland. 1988. Sybron Chemicals Inc. Internal Report.

Stringfellow, W.T. and W.P. Coleman. Preliminary report on summer sulfide control for Worcester County Sanitation District, Ocean City, MD. 1986. Sybron Chemicals Inc. Internal Report.

Stringfellow, W.T. Sampling and site evaluation protocol for soils and groundwaters contaminated with gasoline. 1986. Sybron Chemicals Inc. Internal Report.

Stringfellow, W.T. Study proposal for the evaluation of the use of bacteria for the control of odors in sewage collection lines, City of Charlotte Utilities Authority. 1986. Sybron Chemicals Inc. Internal Report.

Stringfellow, W.T. Determination of root causes of plant upsets at the Menominee Michigan wastewater treatment plant. 1985. Sybron Chemicals Inc. Internal Report.

Stringfellow, W.T. and R. Jack. Biological treatment of coal coking wastewaters, Bethlehem Steel project. 1985. Sybron Chemicals Inc. Internal Report.

Stringfellow, W.T. Waste-stream detoxification at Armco Steel and Coking, Ashland, Kentucky. 1984. Sybron Chemicals Inc. Internal Report.

Stringfellow, W.T. Evaluation of biological treatment plant operating conditions at the Allied Chemicals Asphalt manufacturing plant. 1984. Sybron Chemicals Inc. Internal Report.

Stringfellow, W.T. and C.H. Wilson. Regency Dunes Landfarm Investigation Report, Jacksonville, Florida. July 1981. Task Report to the Environmental Protection Agency. TDD # F4-8008-03.

Karl E. Longley, Sc. D., P. E.
Dean, School of Engineering and Computer Science, 2320 East San Ramon Ave., M/S 94, California State University, Fresno, CA 93740-8028
Phone: (209) 278-2500, Fax: (209) 278-4475, e-mail: karll@csufresno.edu

Dr. Longley has been the Dean of the School of Engineering and Computer Science, CSUF, since July 1996. He served as a department chairman from January 1985 until becoming Dean, and since 1982 he was a professor of civil engineering. Dr. Longley is also a board member of the Central Valley Regional Water Quality Control Board (CVRWQCB) from 1989 until the present. He served as the chairman of the CVRWQCB from November 1992 until January 1997. Dr. Longley also is a member of Board of Scientific Counselors for the Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, a position he has held from February 1994 to the present. Dr. Longley has earned a B.S. in Civil Engineering degree from the University of New Mexico, and M.S. in Sanitary Engineering and Water Resources and Doctor of Science degrees from the Johns Hopkins University. Dr. Longley is a registered professional engineer in the states of California and Maryland. He is a member of numerous professional organizations and he has authored and presented numerous papers and reports.

Dr. Longley has a broad technical background as a civil engineer with a specialty in water resources engineering and management and environmental engineering. During his more than 30 years of experience as a practicing engineer and university professor, Dr. Longley has conducted numerous studies and investigations in the areas of water resources engineering and management, water quality evaluation, industrial waste control, and water control and treatment facilities design. Dr. Longley also has considerable applied and research experience designing and operating wastewater stabilization ponds; using oxidants as disinfectants for water and wastewater systems; treating ground water for removing pesticides; and managing agricultural drainwater and treating it remove selenium.

Since leaving military service in 1981, Dr. Longley's more notable consulting assignments include a determination of optimal criteria for application of high-rate chlorination technology to stormwater-sewage overflows; the identification of critical factors pertaining to reservoir erosion processes; the conduct of a comprehensive hazardous waste management evaluation for a federal facility; the conduct of a training program for a desalting facility operators; the preparation of several draft environmental impact reports and assessments; and, the planning and conduct of a comprehensive operational and optimization study for a municipal water system. His most recent research efforts have focused on the treatment of selenium contaminated soils using a biological process and the removal of dibromochloropropane (DBCP) from groundwater using granular activated carbon

Recent Funding and Project Management Experience:

Responsible Investigator, Ground Water Toxics Monitoring Program - Kern County, A Project Funded by California's Department of Water Resources, July - September 1987.

Responsible Investigator, Ground Water Toxics Monitoring Program - Fresno, Madera, Kings, and Tulare Counties, A Project Funded by California's Department of Water Resources, 1987 - 1988.

Responsible Investigator, Ground Water Toxics Monitoring Program - Merced, Stanislaus, San Joaquin, San Benito, and Monterey Counties, A Project Funded by California's Department of Water Resources, 1989 - 1990.

Project Manager, Microbial Volatilization of Selenium from Soil in Agricultural Evaporation Ponds, A 205(j) Project with Funding by the State Water Resources Control Board in Cooperation with Local Agencies; California State University Fresno and University of California Riverside, 1988 - 1990.

Project Manager, Determination of Selenium in Soils from Experimental Sites in Kesterson Reservoir, A Project Funded by the U.S. Bureau of Reclamation to University of California Riverside and Subcontracted for Soils Analysis to California State University Fresno 1987 - 1990.

Responsible Investigator, West Bakersfield Ground Water Quality Management Study, A Project Funded by the State Water Resources Control Board, 1988 - 1990.

Project Manager, Fugitive Airborne Pesticide Monitoring, A Project Funded by the California Air Resources Board, 1991.

Phillip E. Heck. Ph. D., P. E.

Senior Engineer, Montgomery Watson, 4525 South Wasatch Blvd., Suite 200, Salt Lake City, UT 84124

Dr. Heck is a Senior Engineer with Montgomery Watson. He has a Ph. D. in Environmental Sciences and Engineering from the University of North Carolina at Chapel Hill, a M. S. in Sanitary/Environmental Engineering from University of California at Berkeley, and a B. S. in Civil Engineering from the University of Kansas.

Dr. Heck has a unique background that combines research on novel biological treatment processes (his Ph. D. work addressed the use of enzymes for wastewater treatment) and an extensive practical experience in design, construction, and operation of both full-size and pilot scale treatment systems. In addition to his extensive publication record, Dr. Heck's has served as a Project Engineer on over 20 treatment systems, including several complex biological treatment systems designed for the removal of phosphate and other inorganic nutrients.

His strong background in the practical application of complex biological treatment systems qualifies him as the sole-source subcontractor for technical review and project oversight functions on this project.

Lawrence P. Owens, Ph. D.

School of Engineering and Computer Science, 2320 East San Ramon Ave., M/S 94, California State University, Fresno, CA 93740-8028

Dr. Owens received his Ph.D. at the University of Texas at Austin, where his dissertation research was on the removal of sulfate and selenium from agricultural drainage water using anaerobic biological reactors under sulfate-reducing conditions. Dr. Owens has B. S., M. S., and Ph.D. degrees in Civil Engineering, each with specialization in environmental engineering. He has engineering experience in academic, public, and private sectors.

Dr. Owens has been with the Department of Civil Engineering and the Engineering Research Institute at the California State University, Fresno since 1990. His primary position there has been as research manager for the Adams Avenue Agricultural Drainage Research Center. He was responsible for the construction of the center as well as directing laboratory and field-scale work in the removal of selenium from agricultural drainage water. Dr. Owens has also conducted extensive research in other areas of physical/chemical and biological treatment of water and wastewater.

Dr. Owens has been involved in agricultural drainage and selenium in the San Joaquin Valley since 1984 when he was an assistant engineer for the California Department of Water Resources. There he was involved in the monitoring of drainage and subsurface waters in the State Service area.

Dr. Owens also serves as a consultant on environmental engineering issues and projects.

H. Scott Mountford

Environmental Measurement Laboratory, E. O. Lawrence Berkeley National Laboratory, Berkeley, CA 94720

Mr. Mountford received his B. S. and M. S. in chemistry from the University of the Pacific in Stockton, California. Mr. Mountford is a Principle Research Associate at LBNL where he manages and operates the Environmental Measurement Laboratory supporting research conducted by members of the Earth Science Division, the University of California at Berkeley, and other organizations. This facility is maintained as a California Department of Health Services certified laboratory. Mr. Mountford has extensive experience in providing expert technical and analytical support for geochemical/environmental remediation research and development projects. He has expertise in the development of methods for low level metal and inorganic analysis of environmental samples using ICP/MS, AA, GC/FPD, and other quantitative techniques. Mr. Mountford serves as a consultant on various government projects regarding environmental cleanup/assessment. His extensive experience collecting and managing data for Federal and State government funded projects makes him uniquely qualified to provides data collection QC oversight for this project.

VI. Compliance with Standard Terms and Conditions.

NONDISCRIMINATION COMPLIANCE STATEMENT

COMPANY NAME
ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

The company named above (hereinafter referred to as "prospective contractor") hereby certifies, unle specifically exempted, compliance with Government Code Section 12990 (a-f) and California Code Regulations, Title 2, Division 4, Chapter 5 in matters relating to reporting requirements and t development, implementation and maintenance of a Nondiscrimination Program. Prospective contract agrees not to unlawfully discriminate, harass or allow harassment against any employee or applicant f employment because of sex, race, color, ancestry, religious creed, national origin, disability (includi HIV and AIDS), medical condition (cancer), age, marital status, denial of family and medical care lea and denial of pregnancy disability leave.

CERTIFICATION

I, the official named below, hereby swear that I am duly authorized to legally bind the prospecti contractor to the above described certification. I am fully aware that this certification, executed on t date and in the county below, is made under penalty of perjury under the laws of the State of Californi

COLE B. CANNON
OFFICIAL'S NAME

7/28/97
DATE EXECUTED

EXECUTED IN THE COUNTY OF
ALAMEDA

Cole B. Cannon
PROSPECTIVE CONTRACTOR'S SIGNATURE

Contracts Officer
PROSPECTIVE CONTRACTOR'S TITLE

ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY
PROSPECTIVE CONTRACTOR'S LEGAL BUSINESS NAME

BIDDER'S BOND

We ____

____

____, as PRINCIPAL,

____

____

____

as SURETY, are held and firmly bound unto the State of California in the penal sum of TEN PERCENT (10%) OF THE TOTAL AMO[illegible] OF THE BID of the Principal above named submitted by said Principal to the State of California, acting by and through the Resources Agency for the work described below, for the payment of which sum in lawful money of the United States, well and truly [illegible] made, to the Secretary of the Resources Agency to which said bid was submitted, we bind ourselves, our heirs, executors, administrators[illegible] successors, jointly and severally, firmly by these presents.

In no case shall the liability of the surety here under exceed the sum of $______________________

THE CONDITION OF THIS OBLIGATION IS SUCH,

That whereas the Principal has submitted the above-mentioned bid to the State of California, as aforesaid, for certain construction specifically described as follows, ~~for which bids are to be opened at~~

______________________________, ~~California on~~ ______________________________
~~(Insert name of city where bids will be opened)~~ ~~(insert date of bid opening)~~

for ____

____

____

____

(Copy here the exact description of work, including location, as it appears on the proposal)

NOW, THEREFORE, If the aforesaid Principal is awarded the contract and, within the time and manner required under the specificatio[illegible] after the prescribed forms are presented to him for signature, enters into a written contract, in the prescribed form, in accordance with the b[illegible] and files two bonds with the Department, one to guarantee faithful performance and the other to guarantee payment for labor materials, as requir[illegible] by law, then this obligation shall be null and void; otherwise, it shall be and remain in full force and virtue.

IN WITNESS WHEREOF, We have hereunto set our hands and seals on this ______________________

day of ______________________, 19 ____.

______________________________ (Seal)

______________________________ (Seal)

______________________________ (Seal)

Principal

______________________________ (Seal)

______________________________ (Seal)

______________________________ (Seal)

Surety

______________________________ (Seal)

Address ______________________________

NOTE: Signatures of those executing for the surety must be properly acknowledged.